Designing a hydrogen based energy storage solution for an energy surplus caused by solar panels on building combining offices and laboratories.

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Topic: Designing a long term energy storage system that uses hydrogen as the energy storage medium coupled to a renewable energy source.

Project Background

This bachelor thesis was executed at Huygen. Huygen is an engineering and consultancy bureau specializing in technical building installations and building physics. Their goal is to contribute to a better, sustainable, safer living and working environment. To this end, they want to gain knowledge on the potential uses of hydrogen in the built environment.

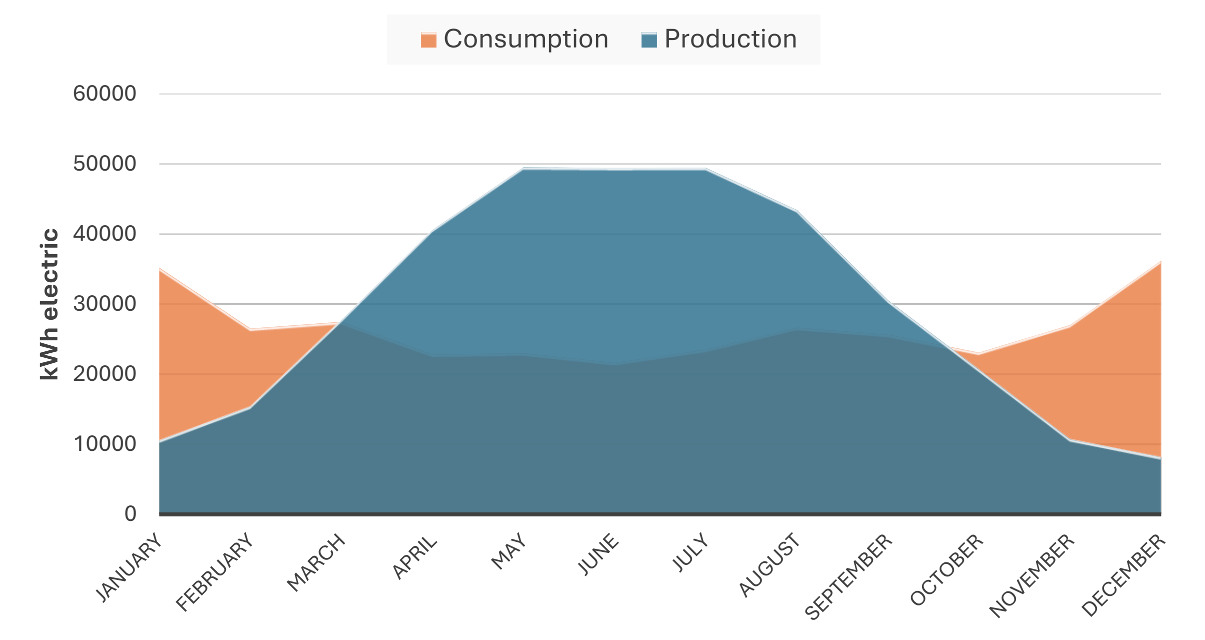
One of the projects Huygen has worked on, was designed with an integrated solar power system and is expected to produce more electricity than it consumes during the sunnier months. However, the electricity production and consumption is not distributed evenly throughout the year. There are some months during which the consumption is higher than the production and there are some months where the production is higher than the consumption.

Instead of delivering this electricity back to the grid, which could be costly, or not utilizing it at all, it is better to store the energy in the months when there is excessive production and use it in the months when the consumption is higher. For this reason a seasonal energy storage system will be designed. Hydrogen was chosen as an energy carrier for this system because the client company Huygen wants to gain knowledge on the possible applications of hydrogen.

The aim of this assignment is to give an overview of current hydrogen technologies related to energy storage systems and to design a hydrogen based energy storage solution for an energy surplus caused by solar panels on a specific building.

Approach

The project began with a comprehensive literature review, exploring aspects such as the properties of hydrogen, hydrogen production methods, hydrogen storage technologies, how energy can be generated from hydrogen and laws and safety regulations. At the same time context research was also conducted. From the context research the amount of surplus energy was found and the requirements were defined.



Graph showing the disparity between the electricity production and consumption.

The problem was divided into three functions; turning electricity into hydrogen, storing the hydrogen and turning it back into electricity. A few solutions to achieve each of these functions were identified from the literature research.

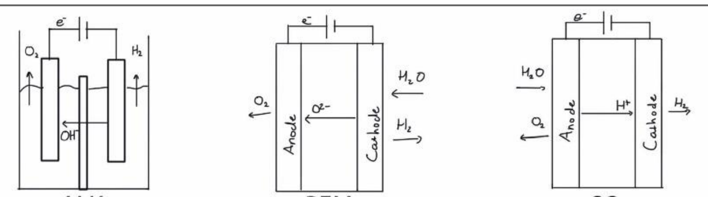
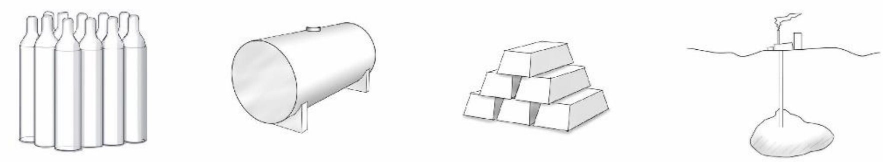
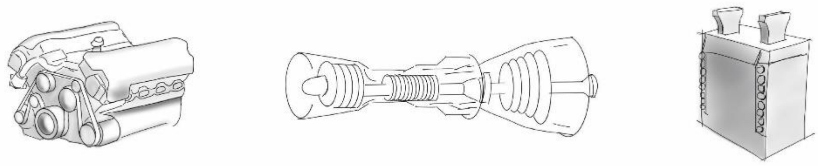
Convert electricity into hydrogen	 ALK, PEM, SO
Hydrogen storage	 Compressed gas, Cryogenic liquid, Solid state, Underground cave
Convert hydrogen into electricity	 ICE, Gas turbine, Fuel cells

Table showing the subsolutions for each function.

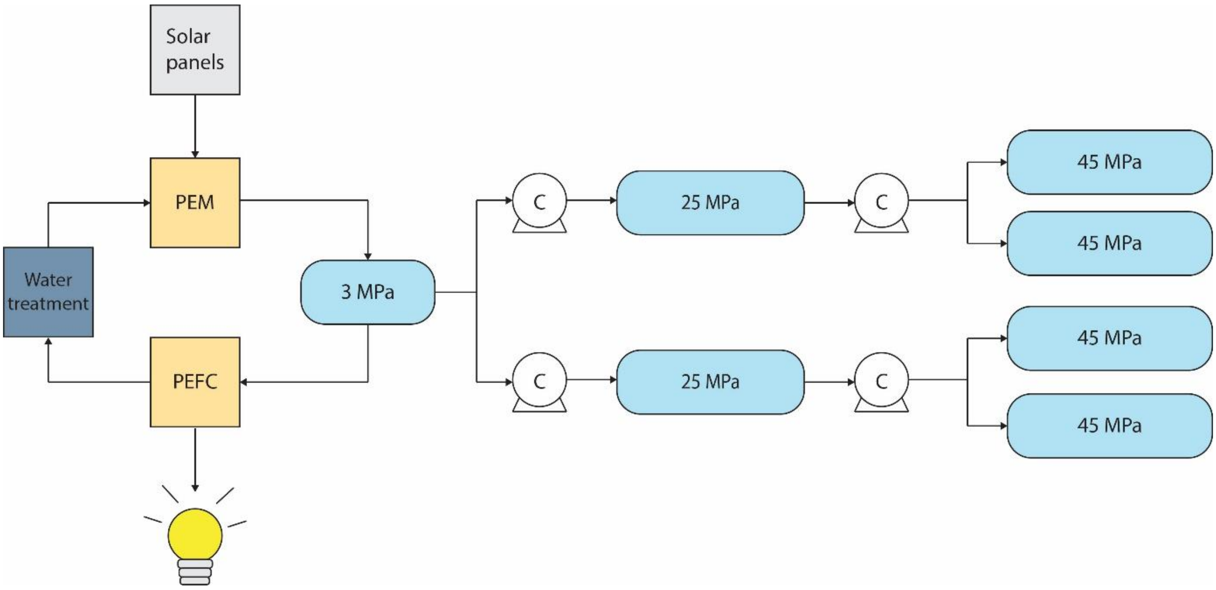
Through the use of weighted decision matrices it was found that a combination of a polymer electrolyte membrane electrolyser, compressed gaseous storage and a polymer electrolyte fuel cell would be a suitable solution. After determining the methods for hydrogen generation, hydrogen storage and energy generation the concept was further developed.

Results

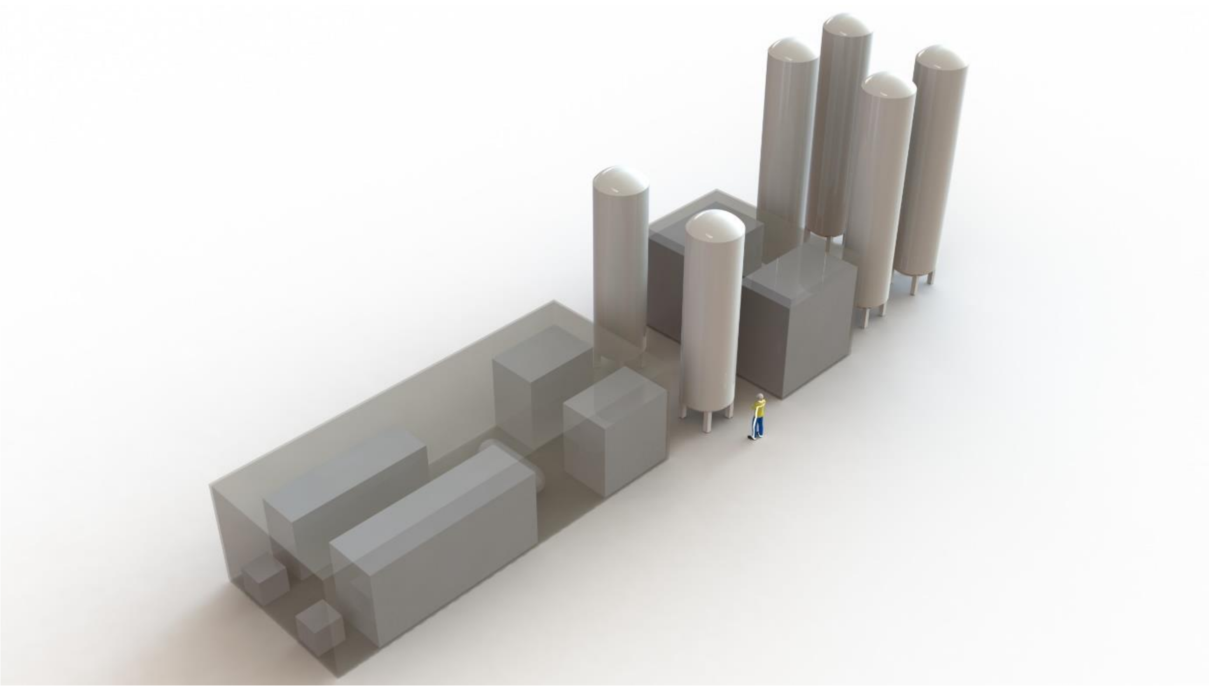
Developing the concept further resulted in a choice to use four 40 kW PEM electrolysers instead of one large 130 kW electrolyser. Because each individual unit will have a lower capacity than the total required capacity each unit will be able to operate at their optimal load more often. They can also be turned on or off as required. Thus making the system more efficient. Another reason for this choice is to create redundancy. So in the case of some of the units breaking or requiring maintenance, other units will still be operational. For the same reasons, four 45 kW fuel cell units will be used instead of one 160 kW unit.

A combination of multiple tanks at different pressures will be utilized. A small 3 MPa tank will be used as a buffer for the compressors but also for the fuel cells. For the storage of hydrogen two 20 vertical tanks with a pressure of 25 MPa and a capacity of 20 m^3 each will be used. In addition to this four vertical tanks with a pressure of 45 MPa and a capacity of 35 m^3 each will be used. In order to create redundancy in the system two sets of tanks and compressors are used. So the storage portion of the system will essentially be split in half, ensuring that it can always at least remain partially operational.

The total storage volume of the system is 180 m^3, however 20% of this has to be kept empty as a safety buffer. This leaves a total storage capacity of 144 m^3 or 4000 kg hydrogen, which is 395 kg more than the amount of hydrogen required to store the surplus energy.
While the storage can be expanded by adding more tanks, the system is limited by the amount of hydrogen the electrolysers can produce.



Schematic overview of the system.



Impression of what the total system might look like.

Conclusion

This thesis has shown that it is technologically feasible to use hydrogen as an energy carrier in an energy storage system coupled to a renewable energy source. However, whether this is also economically feasible still needs to be researched.

Additional recommendations are to look into utilizing the system for combined power and heat generation and for relieving net congestion.